Protecting Critical Ecosystems: Current EPA Regional Activities and Future Agency Opportunities

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Executive Summary

Introduction

Research in both landscape ecology and conservation biology makes clear that habitat loss and fragmentation are the primary threats to biodiversity and ecosystem function (Wilcox and Murphy 1985; Harris and Silva-Lopez 1992; Forman 1995; Wilcove et al. 1998). As land is converted to intensive uses, landscapes become less capable of supporting wildlife, filtering water, abating floods, cleaning air, and providing a variety of other benefits characteristic of functional ecosystems (Daily 1997; Pimentel et al. 2000). In response, an important application of landscape ecology has been the development of regional-scale conservation analysis and planning. Regional-scale assessments are needed to understand relationships between ecosystems and to better integrate protection and management efforts (Harris 1984; Forman 1995; Turner et al. 1995; Harris et al. 1996a). In particular, the identification of critical areas for protecting various ecosystem functions (e.g., critical ecosystems) is essential for conserving natural resources and minimizing the degradation of ecological integrity caused by habitat fragmentation and other impacts (Noss and Harris 1986; Noss and Cooperrider 1994; Margules and Pressey 2000).

In the last two decades, advances in Geographic Information Systems (GIS) technology have led to significant improvements in the amount and quality of spatial data, analysis tools, and applications. These trends have allowed EPA Regions and other organizations to develop spatial data and analytical tools relevant to identifying critical ecosystems. Regional-scale identification of critical ecosystems provides an important foundation for proactive and efficient environmental protection. Therefore, the identification of critical ecosystems could be considered an essential step in EPA’s mission to safeguard the environment for present and future generations. The identification of critical ecosystems can provide a coherent framework of protection and management priorities, and such a framework will allow EPA to target resources more efficiently and develop better policies and programs to protect environmental quality.

This report is a cooperative effort between the University of Florida, the EPA Office of Policy, Economics and Innovation, and EPA Regional offices (Regions 2, 4, 5, 6, 7, 8, and 10) to inventory current EPA Regional critical ecosystem assessments and other relevant projects to identify available data, methods, analytical tools, and gaps in available information. Various EPA Regions have recently conducted, or are developing, GIS applications to identify critical ecosystems or to assess environmental impacts. Although these projects do not always address the same objectives, they all incorporate GIS data and spatial tools relevant for identifying critical ecosystems. Other relevant studies and projects were also inventoried and included in the appendices to serve as an additional resource guide for data, tools, and methods. Based on this collective assessment of available resources, this report identifies the existing opportunities, important challenges and research priorities for enhancing future Regional critical ecosystems assessments.

The report is separated into methods, results, discussion, recommendations, and conclusion sections. The results include the descriptions of the Regional projects, commonalities and unique elements of the Regional projects, and how the projects address categories of analysis for critical ecosystem assessment. The discussion details the opportunities and challenges for enhancing future critical ecosystem assessments and the types of analysis that can be conducted using available GIS data and tools. The recommendations include suggestions for data collection, new or expanded analyses, development of partnerships, and facilitating data and tool sharing. The appendices include more detailed descriptions of the Regional projects and additional information resources for conducting critical ecosystem assessments.

Methods

We collected the primary information for this report through collaboration with seven EPA Regional partners. Each Region provided the available materials describing completed or ongoing projects in their regions most relevant to regional-scale identification of critical ecosystems. Through this process the research team selected the following projects to be included:

Region 2—NEPAssist internet GIS tool for impact assessment
Region 4—Southeastern Ecological Framework (SEF)
Region 5—Critical Ecosystems Assessment Model (CrEAM)
Region 6—GIS Screening Tool (GISST)
Region 7—Synoptic assessment of wetland function model
Region 8—Environmental Monitoring and Resource (EMAP) water resources assessment
Region 10—Rapid Access INformation System (RAINS)

The categories of analysis from the EPA Science Advisory Board's (SAB) Framework for Assessing and Reporting on Ecological Condition (Young and Sanzone 2002) provide the framework for determining which ecological characteristics or functions were addressed by data and analyses in the Regional projects. We then developed descriptions of each Regional project which included the purpose of the project, GIS data used or made available, analytical techniques and spatial tools used, the GIS or other data created, and the SAB categories of analysis these data address. After developing the individual projects descriptions, we compared the Regional projects using tables to show how these projects addressed the SAB categories of analysis. We also identified the commonalities, unique components, and collective gaps of the Regional projects.

The research team also collected additional information through literature review and web searches to identify additional reports, projects, research results, databases, and other information relevant to the identification of critical ecosystems at regional scales. We used the Web of Science as the primary literature internet search engine to identify relevant published literature. EPA's websites include additional projects and other information that may address aspects of critical ecosystem assessment, and we used these to identify other relevant data and projects. We also conducted general web searches to find any additional information including work by other federal agencies or programs, NGO projects and reports, state assessments of critical ecosystems, GIS data websites, etc. This report includes this information in three appendices that incorporate additional summaries of projects or spatial tools relevant to identifying critical ecosystems and list relevant resources including citations, databases, and websites organized by SAB categories of analysis.

Results

The EPA Science Advisory Board (Young and Sanzone 2002) identified six "Essential Ecological Attributes" in the Framework for Assessing and Reporting on Ecological Condition. Three of the Attributes primarily address ecological patterns: landscape condition, biotic condition, and chemical/physical. The other three attributes are meant to address ecological processes: hydrology/geomorphology, ecological process, and natural disturbance. The Framework includes several "reporting categories" under each of the Attributes (Table 1). In this report, we use the hierarchy of SAB Attributes and their reporting categories as an analytical framework to organize data and analyses of the EPA Regional projects and collectively assess current strengths and gaps in existing efforts to identify critical ecosystems. The Regional project descriptions included in this section summarize the data, tools, and analyses included in each project. These descriptions are meant to provide a basic understanding of the data and analyses used and to serve as the basis for determining what is being addressed in current projects and what gaps exist.

Region 2 NEPAssist Tool

NEPAssist incorporates data from GIS servers within EPA and other servers on the internet. The application provides information on a project's potential environmental impacts and offers a tool that allows automatic requests for review to be sent to the EPA. Users may select a study area within the region by ZIP code, city/county and state, Hydrologic Unit Code (HUC), or latitude/longitude. NEPAssist then identifies features relevant to environmental impact assessment within or near the study area.

NEPAssist is intended to be a web-based, user-friendly environmental impact screening application. NEPAssist incorporates nationally-available GIS data and potentially other GIS data sources that are relevant to regional-scale critical ecosystems assessment. Examples include:

1) American Heritage Rivers
2) Wild and Scenic Rivers
3) Drinking water intake points
4) Sole source aquifers
5) Impaired Streams and water bodies
6) Toxic releases
7) Air quality non-attainment areas
8) Wetlands
9) FEMA flood protection areas
10) Listed species habitat
11) Conservation lands including federal, state, and local parks
12) National Estuary Program areas

13) State designated environmentally sensitive area (for New Jersey in the existing application)
14) Hazardous waste sites

These data can be used in critical ecosystem assessments to identify priority areas for protecting biodiversity and ecosystem services or areas where threat abatement or mitigation is needed to reduce the impact of various stressors. These data can address various SAB categories of analysis including Landscape Condition, Biotic Condition, Chemical and Physical Characteristics, and Hydrology and Geomorphology. In the future NEPAssist may include more information on natural communities and focal species from NatureServe and their member state Natural Heritage programs. Such data are a high priority for improving future assessments of critical ecosystems.

Region 4 Southeastern Ecological Framework (SEF)

The Southeastern Ecological Framework Assessment had two major phases. The first phase included an inventory of available GIS data to identify areas of ecological significance across the region. Criteria for ecological significance included areas important for protecting biodiversity and ecosystem services such as water quality and flood abatement. The model then incorporated this information into a process to identify large, connected areas of ecological significance throughout Region 4. There were two major products:

1) The identification of Priority Ecological Areas (PEAs) and Significant Ecological Areas (SEAS--considered lower priority than PEAs) using various available national, regional, and state GIS data;
2) The Southeastern Ecological Framework, which incorporates PEAs, SEAs, and others compatible areas into a network of large Hubs and landscape linkages.

The Southeastern Ecological Framework represents the best, or most important, opportunities to protect large, connected landscapes in Region 4. One of the primary strengths of this approach is the emphasis on protecting large, connected landscapes, which are more likely to support viable populations of focal species and functional ecological processes. In addition, users of the SEF data can also identify smaller areas of significance, select particular focal areas, or specific types of ecological significance by using the PEA, SEA, Hub data. A particular issue with the delineation of the SEF is that in some cases data not available for all states within Region 4 were used in the modeling process. The strength of this approach is that it allows for incorporation of the best available data for identifying areas of ecological significance. In order to use the approach, it was necessary to rely on a query-based process where thresholds were set for each available data set to determine what areas would qualify for PEA or SEA status, and more areas may be identified as ecologically significant in states where more data are available. Since data availability and criteria used to delineate PEAs and SEAs could vary between states, an index-based or other statistical approach was not feasible. Therefore, these methods could reduce the consistency of the results across the region and could make it difficult to compare results across states.

The second phase of the Southeastern Ecological Framework (SEF) assessment was an index-based approach that prioritized areas within the SEF and identified additional areas of ecological significance. In this phase, the research team used only data available for the entire region to identify areas important for protecting biodiversity and a variety of ecosystem services. The modeling identified stressors to ecosystem integrity by assessing existing impacts from intensive development and the potential for future conversion to intensive development. The prioritization phase used several data sets that were not available during the delineation of the SEF, along with data used to delineate the SEF that was available for the entire region. This process established indices that were consistent for all of Region 4 and can be used to identify areas of ecological significance using various criteria both within the SEF and within the entire region.

One of the primary issues for both SEF phases and for other regional assessments of critical ecosystems is data availability. Available GIS data and tools continue to evolve rapidly, but more information is needed to better identify areas important for protecting intact or restorable landscapes, important natural communities and viable populations of focal species are needed to ensure that results of these assessments capture all areas of significance and can be prioritized to focus on the areas most important for maintaining biodiversity. The same is true for ecosystem services including more comprehensive assessments of areas needed to protect water and air resources. This will be discussed further in the discussion section below.

Region 5 Critical Ecosystems Assessment Model (CrEAM)

The Region 5 Critical Ecosystems Assessment Model (CrEAM) is intended to identify areas of ecological significance (critical ecosystems) throughout Region 5. CrEAM combines individual indicators into major categories of ecological significance or stressors, which is similar to the prioritization phase of the Region 4 SEF project. Region 5 organized indices of ecological significance into three major categories:

1) Ecological diversity;
2) Self-sustainability; and
3) Land cover and species rarity

The ecological diversity criterion included indices addressing land cover diversity, potential climatic influences on diversity, land cover similarity to potential natural vegetation, and patch size/landscape intactness. The self-sustainability criterion included two major components:

1) Fragmentation, which addressed patch shape/core habitat; aquatic habitat fragmentation (impoundments); road densities; patch sizes of land cover types; and similarity to potential natural vegetation, and
2) Stressors which addressed disturbance from airports and urban land uses; major pollution sources, air and water quality, and aquatic habitat disturbance (dams).

The rarity criterion addressed land cover type rarity within each ecoregion, degree of species rarity, number or rare species, and number of rare taxonomic groups summarized by quad. Region 5 then combined these three primary indices to create one cumulative score of potential ecological significance throughout the Region.

All of the data used in creating these indices are either currently available nationally or, in the case of Natural Heritage quad summary data, could be obtained in other regions. All tools used to create the individual and combined indices are also readily available. Overall, the CrEAM process represents a concise and repeatable methodology that would be at least relatively easy to apply to other regions. However, as also discussed in the Region 4 summary, more GIS data and tools are needed, or results of other assessments could be used, to strengthen aspects of such regional-scale critical ecosystem assessments. In particular, more detailed information on biodiversity conservation needs would be helpful, including the availability of more precise rare natural community and species location data (versus quad summary data), habitat models of selected focal species, and, when feasible, viability assessments for selected focal species. In addition, more information is needed to conduct more detailed assessments of specific ecological services including the identification of areas needed to protect drinking water sources and other associated water and air quality issues.

Region 6 GIS Screening Tool (GISST)

EPA Region 6 GIS Screening Tool (GISST) is primarily an environmental impact assessment tool that incorporates a vast array of GIS data and applies a consistent scoring structure to support sound environmental decision making. The system is designed to be flexible so that it can be applied to a variety of programs or projects and the system may be applied at spatial scales ranging from local to regional. The GISST system consists of criteria (environmental vulnerability and environmental impact criteria) and imposes a scoring structure using available data sets and expert input. Criteria are evaluated using a mathematical formula and the scoring structure consists of the criteria and a ranking system, which uses 1 to indicate low environmental concern and 5 to indicate high concern. Assessment criteria incorporated in the GISST system include the broad groups of water quality, ecological, air quality, socioeconomic, toxicity, and CAFO (concentrated animal feeding operations). Advantages of GISST include the flexibility of the system to add new criteria at any time and the ability to apply GISST at varying scales for local to regional projects.

As an impact assessment tool, GISST is more similar to the Region 2 NEPAssist tool than to the critical ecosystem assessment projects conducted in Region 4 and Region 5. However, though Region 6 GISST is an impact assessment application, it incorporates a wide variety of data and analyses relevant to regional-scale critical ecosystem assessments. Many of the GIS data incorporated into the application are useful for identifying both ecologically significant areas and relevant stressors including:

1) Surface water and ground water quality
2) Aquifer significance
3) Channelization
4) Floodplains

5) Air quality
6) Pollution sources
7) Landscape composition
8) Wetlands
9) Listed species
10) Wildlife habitat
11) Habitat fragmentation
12) Road densities
13) Managed lands

The index ranking approach is also similar to the ranked index approaches used in the prioritization phase of the Region 4 SEF project and Region 5 CrEAM. As discussed in the summaries for the Region 4 and Region 5 projects, such data address many aspects of critical ecosystem identification but not all. More specific data are needed to more thoroughly identify areas needed to conserve biodiversity, especially viable populations of focal species, and more information and tools are needed to address ecological services including hydrological and air resource protection.

Region 7 Synoptic Assessment of Wetland Function Process

The Region 7 synoptic assessment of wetland function was developed to identify priority wetlands for conserving wetland species biodiversity. The method prioritizes sub-basins (eight-digit Hydrologic Unit Codes) within the region in which conservation actions would be expected to have the most benefits for wetland biodiversity conservation. Region 7 developed three separate indices to prioritize sub-basins within the region, which all incorporated various indicators of habitat quality and focal species priority. Region 7 developed all habitat indicators using the National Land Cover Dataset (NLCD), and used the 1995 Natural Heritage Program database to develop the focal species priority indicators. Index values were derived for each sub-basin, which were then ranked in terms of wetland importance. Region 7 did not combine the results of the three indices, but instead compared them in terms of index score correlation and general spatial patterning. The first habitat quality index combined the following indicators:

1) Agricultural density
2) Wetland density
3) Global rarity score
4) Endemism score

The second habitat quality index included the same four indicators but also added wetland habitat diversity, mean distance between wetland patch centers, and mean wetland patch size. The third index combined the global rarity score and endemism score indices with a habitat quality categorical modifier to the global rarity score. In this application of the model, the scores of all three of the indices were highly correlated and general spatial patterning of the ranks was qualitatively similar.

The assessment serves as a screening tool to target resource management and conservation efforts at a sub-basin scale, which is an important distinction between this application and especially the Region 4 and Region 5 critical ecosystem assessment projects. The Region 7 represents a "geographic summary" assessment approach, where large geographical units are identified as priorities based on the comparison of relevant ecological data summarized for each geographic unit. In contrast, the Region 4 and Region 5 projects can be described as primarily (though not exclusively) pixel-based, or cell-based, decision support models, where the decision units are at least relatively small geographic areas that more specifically identify areas containing ecological resources of interest or stressors of concern. Though more spatially specific approaches may be preferred when feasible, both approaches provide benefits for regional-scale assessments of critical ecosystems and are potentially complementary. The primary reason for the utility of both approaches is that many available GIS data and analytical methods lend themselves to the development of summary statistics for larger geographic units versus more specific identification of areas of significance. For example, indices such as mean patch sizes and mean distance between patches are at least more easily applied to summary geographic units than to pixel-based approaches. As noted by the authors of the Region 7 synoptic wetland assessment, these approaches can be complementary. Larger geographic units can be used where appropriate to summarize data and utilize methods difficult to apply to more spatially-explicit approaches in order to prioritize them. More spatially explicit approaches can then be used to identify the specific areas of ecological significance within higher priority geographic units and to also identify specific areas within lower priority geographic units that are also worthy of conservation attention. Finally, it should be noted that the Region 7 methodology is currently being studied for application to a broader array of resources including priority uplands and the inclusion of additional indices to assess relative significance. This includes the development of representation or irreplaceability analyses that can be an important tool for assessing the importance of ecosystems, which is included in more detail in the discussion section of this report.

Region 8 Environmental Monitoring and Assessment Program (EMAP) Water Resources Assessment

The EPA Region 8 Environmental Monitoring and Assessment Program **(**EMAP) water resources assessment is an ongoing project to compile and analyze available biological monitoring and stressor data to produce a Regional ecological assessment of stream condition within Region 8. Using a condition ranking of good, marginal and poor condition, the assessment is designed to determine the length and location of streams with these conditions; inventory the condition of resources using the same ranking guide; and identify the frequency and magnitude of the stressors impacting resource condition along these streams. Additional goals are to determine the associations between conditions and stressors; predict locations of the condition classes and stressors within each assessment unit. The landscape reporting units for the assessment units in the project are proposed to be 3km and 5km grid cell sizes.

Analysis criteria include various characterizations of ecological conditions of streams and rivers. Criteria are subdivided into groups representing biological and habitat integrity and various stressors. The indicators used in the pilot project include:

1) Fish, macroinvertebrate, and periphyton community structures
2) Physical habitat (in-stream and near-stream)
3) Ambient chemistry (nutrients and major ions)
4) Fish tissue (heavy metals and organic contaminants)
5) Watershed characteristics

Rankings for condition classes are on a qualitative basis of good, marginal, and poor. Landscape metrics will be used to characterize stressors and stream condition, and stressor association with surface water monitoring sites will be quantified by developing landscape indicators for each catchment/basin, landscape metrics for catchments/basins, and landscape models. Surface water measurements and indicators will be integrated with landscape metrics to produce landscape indicators.

Though the Region 8 project is more specifically focused on water resource assessment and monitoring and the integrity of aquatic biodiversity, its objectives and method development are relevant to the regional identification of critical ecosystems. One of the key features of this project is the linkage of biotic integrity and water quality data collected in the field with landscape models using land cover data and other GIS information. The Region 8 project will likely provide important tools for assessing watershed integrity at regional scales, which will help close an important gap in existing critical ecosystem assessments. One of the future questions for this work is the applicability of landscape indices for aquatic ecosystem integrity developed within the study area to other regions.

Region 10 Rapid Access INformation System (RAINS)

RAINS is an intranet/internet data access application that allow users to select a variety of GIS and other data relevant to their area(s) of interest. The system incorporates access to data from a variety of national, regional, and state sources including:

1) Environmental justice data
2) Air quality data
3) Impaired waters data
4) Salmon species and stock distributions
5) Bull trout distributions
6) Stream temperatures within watersheds
7) Sensitive habitats and species data
8) STORET
9) National EPA EnviroMapper
10) Census TIGER Mapper
11) TerraServer Imagery
12) TopoZone Imagery
13) State environmental mapping websites

The Region 10 data accessing system could be relevant to organizing and accessing data for critical ecosystem assessments in all regions. The RAINS structure could be used as a template for organizing all relevant GIS data, analytical tools, and internet links to allow users to quickly access all available GIS data, methods and tools relevant to conducting regional-scale critical ecosystem assessments.

Commonalities among Region Critical Ecosystem Assessment Projects

The National Land Cover Data (NLCD) is the most important data set used in all of the Regional assessment projects. In fact, this Landsat-based land cover/land use data are the backbone of most analyses done in the Regional assessments. Regions use NLCD to identify coarse classes of upland and wetland natural communities, low intensity land uses, and high intensity land uses in various analyses to address various SAB categories of analysis, especially Landscape Condition and Biotic Condition. Regional assessments also used the NLCD data to address the Chemical and Physical Characteristics (Region 8 models linking land use the Total Organic Carbon) and the Hydrology/Geomorphology categories of analysis.

Region 2, Region 4, Region 5, Region 6, Region 7, and Region 10 have all incorporated listed or imperiled (focal) species occurrence information in some form. However, the data used varied in source, coverage, and resolution. Region 4 obtained species occurrence locations data from only three of the eight state Natural Heritage programs to use in the delineation of the SEF. Region 4 also obtained imperiled and listed species priority areas (summarized by EMAP hexagons), at-risk aquatic species summarized by watersheds and critical watersheds for aquatic biodiversity (using eight-digit HUCs) from NatureServe (Stein et al. 2000). Region 5 used Natural Heritage rare/imperiled species data summarized by 7.5 minute quads for their entire region, which was obtained by working with the 6 state Natural Heritage programs in the Region. Region 6 developed a listed species analysis using federal and state listed species occurrence data from the Texas Parks and Wildlife Department. Region 7 conducted an analysis of rare/imperiled species and endemism using a 1995 Natural Heritage Program data set of species occurrences obtained through agreements with each of the four state Natural Heritage programs.

Region 2, Region 5, Region 6, and Region 10 used STORET (EPA's primary computerized data system) and Toxic Release Inventory Program (TRI) data. Region 5 and Region 6 applied these data to develop several water and air quality analyses. Region 8 is also incorporating various water quality and related data in their assessment of water resources. Region 4 did not use water quality data directly but instead identified a number of national and state designated water bodies identified as having outstanding aquatic resources or resources requiring a certain level of protection.

Region 2 incorporates Wild and Scenic River data and Region 4 also used this data as part of an important water body buffer analysis. Region 2, Region 4, and Region 6 all incorporate FEMA floodplain data. The Region 2 and Region 6 impact assessment applications both use sole source aquifer data.

Region 4, Region 5, Region 6, and Region 8 all incorporate analysis of road densities within their models. Region 4 also includes identification of large roadless areas. All Regions used U.S. Census Bureau TIGER/Line files as the source of road data. Region 2, Region 4, and Region 6 incorporated conservation lands data although from a variety of sources. Finally Region 2 and Region 4 both used some data on from various states identifying environmentally sensitive areas or important wildlife habitats.

All of the Regional assessments used the suite of ESRI GIS software products including ArcView 3.x, Arc-Info, and ArcGIS as the primary GIS analysis tool to conduct most analyses.

Regions 4, 5, 6, and 7 identify areas containing focal species using Natural Heritage occurrence data. The Natural Heritage ranking system of Global ranks (G ranks) is typically used to either select species occurrences included in the models or to prioritize or weight occurrences. In this ranking system G1 indicates a species that is globally imperiled and G5 indicates a species that is secure or common.

Regions 4, 5, 6, and 7 include similar versions of patch size analyses or fragmentation indices to identify large, intact areas as generally the most ecologically significant or sustainable. Analyses include identifying patches in various size classes or patches that meet a size threshold.

Regions 4, 5, and 6 include analyses of patch shape/fragmentation where patches are either measured using perimeter/area ratios or comparison of patch shape to a circle. Such analyses are useful in combination with patch size and intactness analyses to identify areas less likely to be influenced by negative effects from surrounding land uses (Forman 1995; Farina 1998).

Landscape composition is an important aspect of various analyses in Regions 4, 5, 6, 7, and 8. Analyses often use neighborhood (or shifting-window) algorithms to identify the density of either ecologically-important land cover types such as wetlands or stressors such as urban land uses. Regions 4, 6, and 7 all also include various wetland analyses as a primary modeling component.

Regions 4, 5, and 6 conducted analyses of habitat diversity (Region 6 did so only for wetlands) to identify priority areas and distance from urban land uses as a threat/stressor assessment.

Finally, Regions 4, 5, 6, 7, and 8 all included calculations of road densities as an important indicator of various stressors associated with roads (Trombulak and Frissell 2000; Forman et al. 2003).

Unique Regional Assessment Features

The Region 2 impact assessment tool incorporates National Heritage Rivers and National Estuary Program data. It is also unique since it is an internet application, which allows users to identify their area of interest for impact analysis by using onscreen digitizing. The application then identifies environmental features of interest within or near the study area.

The Region 4 assessment included several additional national and state datasets as indicators of priority ecological areas in the delineation of the Southeastern Ecological Framework (SEF). Region 4 identified significant stands of longleaf pine (*Pinus palustris*) and older forest stands of various types from Forest Inventory Assessment from the U.S. Forest Service. Maps of black bear populations (*Ursus americanus*) were the basis for developing a priority potential habitat map for the species (Maehr 1984; Wooding et al. 1994), which also served as a surrogate analysis to identify large, intact habitat blocks for other species of conservation interest (Maehr 2001; Maehr et al. 2002; Hoctor 2003). Region 4 incorporated strategic habitats needed to conserve viable populations of focal species delineated by the Florida Fish and Wildlife Conservation

Commission. National Estuarine Research Reserves, Wild and Scenic Rivers, Aquatic Preserves, areas with high densities of start stream reaches (Forman 1995), FEMA floodplains, and intact riparian vegetation around all streams were the base for identifying wetland and upland buffers to protect water quality. Region 4 identified priority coastal lands for storm protection with the Coastal Barrier Resources Act lands from FEMA data. To complement road density analyses, Region 4 also identified roadless areas as critical ecosystems due to the importance of the lack of road impacts (Noss and Cooperrider 1994; Trombulak and Frissell 2000; Forman et al. 2003). After identifying priority areas and larger areas of priority areas (Hubs), Region 4 also conducted a landscape connectivity analysis between Hubs using the least cost path function in Arc-Info GRID.

The Region 4 assessment incorporated other unique data and analyses in the Regional prioritization phase that followed delineation of the SEF. DRASTIC data was the input to identify areas most vulnerable to groundwater pollution. Region 4 also buffered ground water and surface water intake points from EPA to coarsely identify potential protection zone priorities. Interior forest analysis was conducted to identify areas potentially most important for supporting forest interior species. Region 4 assessed potential resource-based recreational demand with gravity models based on the influence of population centers, amount of conservation lands, relevant points of interest, and water-based recreation potential. Potential threats from existing and potential future development were characterized using proximity to, and density of, roads and urban land use. Finally, the Region 4 assessment prioritized the Hubs and Linkages within the SEF with a number of content and context analyses that addressed resource significance and ecological integrity.

Region 5 applied regionally consistent data in their Critical Ecosystems Assessment Model that included a number of unique elements including appropriate vegetation analysis, aquatic ecosystem fragmentation, and various stressor analyses. Region 5 used climate data to identify areas with the highest average daily temperature and daily precipitation. Region 5 combined Kuchler Potential Natural Vegetation and a digital elevation model (DEM) to develop an analysis comparing existing land cover to potential natural vegetation where land cover that matched the appropriate potential natural vegetation class was given higher priority. Region 5 also analyzed land cover rarity for each ecoregion to identify rarer land cover types as higher priorities. Region 5 conducted analyses of water bodies and watersheds impacted by dams as a stressor/threat analysis. Other unique stressor/threat analyses in the Region 5 analysis include: airport noise, Superfund sites, and hazardous waste cleanup sites.

The Region 6 assessment model includes many unique indices relevant to identifying/prioritizing areas based on their ecological significance. Unique water quality analyses/indices include: surface waters supporting their designated use, surface water quantity, distance to surface water, ground water probability and quality, unified watershed and clean water act state priority data, average stream flow, sole source aquifer data, channelization, individual well water sources, septic tank and cesspool use, and soil permeability. Ecological analyses/indicators include: an agricultural lands index (where higher percentages of agricultural lands were given a higher priority to indicate the potential for farmland loss), an NLCD-based index of wildlife habitat and wildlife habitat quality, landscape texture and aggregation measures (relevant to fragmentation), Endangered Species Act compliance data, and percent of watershed/geographic area occupied by potential polluting facilities. Region 6 also created indicators for air quality based on ozone nonattainment data, and developed a unique potential stressor assessment to address concentrated animal feeding operations (CAFO). Finally, as part of their assessment model for environmental impacts Region 6 incorporated many socioeconomic criteria to address potential environmental justice and related issues.

Region 7 assessment developed several unique analyses based on NLCD and other data to identify basins with higher priority wetlands. Region 7 calculated agricultural land use density where basins with more agriculture were given lower priority due to the potential for wetland impacts. Region 7 conducted an endemism analysis where basins containing species found in only in one or a few basins were given higher priority. A mean distance between wetland analysis prioritized basins that had lower mean distances. Finally, the Region 7 assessment used principal components analysis to create a wetland priority index with a combined ranking based on the rarity (level of imperilment) of species and habitat quality within each basin.

The Region 8 assessment is still in progress with most analyses not completed. The key unique feature of this project is the linkage of biotic integrity and water quality data collected in the field with landscape models using land cover data and other GIS information. Specific analyses include land cover/land use based indicators of total organic carbon, phosphorous, and nitrogen.

The Region 10 RAINS is a data organization and accessing tool that significantly enhances access to a variety of national, regional, and state data sets that can be used to identify critical ecosystems or to conduct environmental impact assessments.

Addressing SAB Framework Essential Ecological Attributes

Collectively the Regional assessments analyses address many of the SAB reporting categories (Table 27-Table 30). All five of the Regional critical ecosystem assessment projects (Region 4, Region 5, Region 6, Region 7, and Region 8) address the three reporting categories (extent of ecological system/habitat types, landscape composition, and landscape pattern and structure) for the SAB Landscape Condition EEA. In general, all of the assessments also address the ecosystems/communities and the species/populations reporting categories for the Biotic Condition EEA. Three of the regions (Region 5, Region 6, and Region 8) collectively address various aspects of the nutrient concentrations, trace inorganic and organic chemicals, other chemical parameters, and physical parameters reporting categories for the Chemical and Physical Characteristics EAA. Region 4, Region 5, Region 6, and Region 8 potentially address the dynamic structural characteristics reporting category for the Hydrology/Geomorphology EAA.

Categories of Analysis Not Addressed in the Assessments Collectively

Few categories of analysis from the SAB Framework for Assessing and Reporting on Ecological Condition were not addressed in some way by the Regional assessments (Table 27-30). However, two of the SAB categories, Ecological Processes and Natural Disturbance Regimes, are not addressed directly by any of the Regional assessments

(Table 30). Others that are only marginally addressed include the organism condition reporting category under the Biotic Condition EEA and the surface and groundwater flows and sediment and material transport reporting categories under the Hydrology and Geomorphology EEA (See Table 28 and Table 30). Finally, all of the reporting categories under Chemical and Physical Characteristics EEA are addressed by several of the Regional assessments but not all (Table 29). There are at least three primary reasons for these gaps in analysis: 1) appropriateness of the SAB Framework for assessments of critical ecosystems versus reporting on ecological condition or ecological monitoring; 2) purpose and goals of the various assessments; 3) difficulty in matching various analyses in the Regional assessments to SAB categories.

Discussion

All of the EPA Regional assessments were conducted with different goals using various data and methods. The Region 2 project provides an internet-based impact screening tool that incorporates a number of GIS datasets relevant to identifying critical ecosystems. The Region 4 and Region 5 models are the most similar and most directly address the issue of identifying critical ecosystems. The Region 6 project is a very detailed impact assessment model with a number of component analyses that are relevant to the identification of critical ecosystems. The Region 7 model has the very specific goal of identifying basins that are the highest priority for wetland protection, but this assessment also developed analyses that can be used to identify critical ecosystems. The Region 8 project is more specifically focused on water resource assessment and monitoring and the ecological integrity of aquatic biodiversity. The project includes elements that are relevant to closing gaps in aquatic resource assessments. The Region 10 data system could be relevant to organizing and accessing data for critical ecosystem assessments in all regions.

Another important comparison of the Regional assessment projects is the scale, or resolution, of analysis. First, individual grid cells (pixels) can be, and are, used in assessments of critical ecosystems when data resolution allows. Examples include an output resolution in the Region 4 analysis of 90 meter grid cells and a 300 meter grid cell output resolution in Region 5. Second, summarizing by selection units (such as watersheds) is another method conducted based on either the goals of the assessment or the input data and types of analyses that require selection units to address data resolution or analytical issues. The Region 7 wetlands prioritization used sub-basins (delineated by US Geological Survey eight-digit Hydrologic Unit Codes) to identify watersheds where conservation action would be expected to have the most benefits for wetland biodiversity.

Though one obvious goal of GIS assessments is for results to have as high a resolution as possible, both assessment scales can be important to make the best use of available data and analytical tools. Though more spatially specific approaches may be preferred when feasible, both approaches provide benefits for regional-scale assessments of critical ecosystems and are potentially complementary. The primary reason for the utility of both approaches is that many available GIS data and analytical methods lend themselves to the development of summary statistics for larger geographic units versus more specific identification of areas of significance. For example, indices such as mean patch sizes and mean distance between patches are at least more easily applied to summary geographic units than to pixel-based approaches. As noted by the authors of the Region 7 synoptic wetland assessment, these approaches can be complementary. Larger geographic units can be used where appropriate to summarize data and utilize methods difficult to apply to more spatially-explicit approaches in order to prioritize them. More spatially explicit approaches can then be used to identify the specific areas of ecological significance within higher priority geographic units and to also identify specific areas within lower priority geographic units that are also worthy of conservation attention.

Current Regional assessments address the primary categories of analysis for identifying critical ecosystems, but they do not address all SAB Framework categories or other analysis categories that could be incorporated. Some of the SAB categories are more applicable to local-scale monitoring and are either impossible or very difficult to address at regional scales (See Young and Sanzone 2002; pp. 21-22).

The identification of critical ecosystems is an extension of reserve design, which strictly defined is the science and art of identifying and designing the areas needed to effectively conserve biodiversity (Harris 1984; Noss and Cooperrider 1994; Noss 1996; Margules and Pressey 2000). In the case of critical ecosystems and EPA mandates, the protection of ecosystem services, the goods and services provided by natural/semi-natural lands and waters, is also paramount (Daily 1997; Daily 2000; Pimentel et al. 2000).

The identification of stressors is also important. First, the absence, or low-level, of stressors can be taken as a sign that an area may still have at least relatively high ecological integrity. This would include areas with no roads or low road densities, distant from urban land uses, at least largely free of various forms of pollutions, and not dominated or significantly impacted by invasive species (Noss and Cooperrider 1994; Noss et al. 1999; Groves et al. 2000). Second, stressors can be useful for identifying where priority ecological resources are threatened by inappropriate activities or conditions. For example, watersheds that are critical for aquatic biodiversity but are also threatened by pollution or other stressors are a high priority for threat abatement (Stein et al. 2000).

In the following sections on opportunities and obstacles, the discussion is organized either by SAB Framework Essential Ecological Attributes or the individual reporting categories in a manner that makes the most sense for critical ecosystem assessments. For example, the discussion of the Landscapes EEA does not refer to the individual reporting categories (extent, composition, pattern and structure) since these reporting categories are often combined when identifying critical ecosystems. We discuss the protection of water and air resources within a combined discussion of the Chemical and Physical and Hydrology and Geomorphology Attributes. We discuss stressors where they are relevant to specific analyses addressing various categories of analysis.

Opportunities and Challenges

Although almost all of the Regional projects described and analyzed in this report were created to address different purposes, there is a common framework regarding input data, tools, and analytical methodologies that provides a strong foundation for sharing information to conduct significantly enhanced Regional critical ecosystem assessments in the future. The National Land Cover Data (NLCD) is a primary component of all existing Regional projects, many Regions use Natural Heritage occurrence data to identify areas important for protecting focal species, and all Regions use road data to assess issues associated with high road densities. All Regions use ESRI GIS software products as the primary tool for conducting analyses, so sharing methods for addressing aspects of critical ecosystem identification should be relatively straightforward for all analyses using ESRI software.

Obstacles include various data and some tool and analysis issues. Primary data issues include the timeliness and classification detail of the NLCD, the consistent availability of Natural Heritage data for all Regions, and lack of more specific information to identify habitat needed to conserve viable populations of focal species and functional landscapes to protect biodiversity and provide ecosystem services.

Not all analyses can be done, or at least easily accomplished, using ESRI ArcGIS, ArcView, or ArcInfo. Some regions have used other analytical tools as alternatives including the Analytical Tools Interface for Landscape Assessments (ATtILA) Version 3.0, Fragstats 3.3 habitat fragmentation and landscape analysis software, and the APACK software program, which is a potential alternative to Fragstats for calculating various landscape metrics. Fragstats can calculate a wide variety of potential fragmentation and landscape metrics but is generally not capable of handling the processing requirements of regional-scale analyses. APACK may be a viable alternative to Fragstats for calculating landscape metrics at regional scales but more information is needed about the software including potential interface or transferability with ESRI GIS software. Sharing information between regions about these tools regarding their analytical capabilities and possibly standardizing (or at least increasing the accessibility) the use of certain tools for conducting specific analyses would be useful.

The development of assessment methods to identify areas important for protecting, or restoring, ecosystem services is a primary analysis issue. In particular, data and quantitative assessments of areas important for flood control/abatement, protecting water quality for drinking water sources and other purposes, and areas important for abating air pollution including carbon sequestration are all important gaps in current critical ecosystem assessments. Furthermore, although Regions address biodiversity in a number of ways in all of the Regional projects, the science and art of “reserve design” continues to grow within the discipline of conservation biology (Harris 1984; Noss and Cooperrider 1994; Harris et al. 1996b; Barrett and Barrett 1997; Soulé and Terborgh 1999; Margules and Pressey 2000; Groves et al. 2003; Noss 2003). Reserve design can include detailed analyses of landscapes, natural communities, and species that require more specific data and can be very time intensive. Therefore, one of the important issues for regional-scale assessments of critical ecosystems is the acquisition of data and development of methodologies that address these aspects of reserve design to the extent practicable, and/or development of valid surrogate analyses to identify areas needed to protect biodiversity (which has been done in most of the existing Regional projects), and/or development of partnerships with other agencies and organizations to share their expertise and their existing assessments of biodiversity. Finally, methods of selecting criteria for determining ecological significance and sensitivity analyses are important issues that should be addressed in future Regional critical ecosystem assessments.

Table 31 includes the categories of analysis and indicates whether these are addressed in current Regional analyses and therefore also summarizes suggestions for improving future efforts for identifying critical ecosystems at regional scales. This table is intended to show what the Regional projects address regarding various critical ecosystem analyses to serve as an indicator of what could be done in future assessments. It must be noted that these projects were not all designed to specifically identify critical ecosystems are all aspects of critical ecosystems, and other aspects of critical ecosystem assessment may be addressed in other currently ongoing efforts within Regions. Therefore, gaps in the analyses included in this table do not indicate relative importance or quality of a project or represent all research efforts that may be ongoing within various Regions.

Recommendations

A. Improving data and analytical tools

1) Develop a schedule for production of NLCD that meets the needs of Regions for a timely land cover and land use dataset. The schedule for developing new version of NLCD should be: 1) acquire the imagery; 2) use existing technology to develop NLCD quickly so that classified data are as close to being concurrent with base imagery as possible; and 3) use intervening time between final product and next acquisition to do the research to make NLCD better, but to always be ready to develop the next version in a short time frame (such as less than two years).
2) Procure a national version of Natural Heritage species and natural community occurrence data from NatureServe. These data should include the occurrences at original resolution with proper provisions for protecting the source data from FIA requests. Some state Natural Heritage programs also have data on significant natural areas, which could be useful if obtained.
3) Procure GIS tools such as APACK and SITES (or other reserve efficiency or irreplaceability software) in all regions to augment existing tools such as ArcGIS and ATtILA. Develop user guides to tools that address how these tools can be used to conduct specific critical ecosystem analyses.
4) Develop an EPA GIS database and tool repository specifically for regional-scale identification of critical ecosystems for data and tools that are currently not readily accessible. Develop a resource guide for locating all other relevant GIS data and tools that are available on the internet. The repository should include copies of all relevant nationally available GIS data, copies of relevant software tools, and guides to methodologies for applying tools to conduct specific critical ecosystem analyses.

B. Develop partnerships within and outside EPA to improve and implement assessments

1) Work with EPA Office of Research and Development's (ORD) Regional Environmental Vulnerability Assessment (ReVA) program to share national and regional data sets on ecological indicators and other relevant GIS data or tools. ReVA's themes, 1) measuring and monitoring environmental condition; 2) diagnosing potential causes for impaired condition; 3) forecasting future environmental stressors and conditions; and 4) developing effective restoration and remediation activities, are all relevant to identifying critical ecosystems.
2) Consider developing a partnership with The Nature Conservancy to use ecoregional planning data, methods, or results in critical ecosystem assessments.

3) Work with the U.S. Geological Survey (USGS) to make various data available sooner for conducting critical ecosystem assessments including state and regional GAP analysis and enhanced hydrology data.
4) Consider partnerships with states to help develop and/or use state strategic wildlife conservation plans to enhance critical ecosystem assessments.
5) Develop discussions and possibly a workgroup among EPA Regions and other relevant EPA organizations for incorporating review of criteria for identifying critical ecosystems, thresholds for determining ecological significance, and developing feasible sensitivity analyses for regional-scale critical ecosystem assessments. This was one of the Science Advisory Board's (SAB) recommendations from their review of the Region 4 Southeastern Ecological Framework. The Region 5 Critical Ecosystem Assessment Model is currently being reviewed by SAB, and the Region 6 GIS Screening Tool is scheduled to be reviewed soon. Once completed, all of these reviews could serve as a collective basis for enhancing future critical ecosystem assessments.

C. Enhancing landscape analyses in Regional critical ecosystem assessments

1) The landscape category of analysis is probably the best addressed in current Regional assessments. However, analyses that identify intact landscapes are very important and all Regional critical ecosystem assessments should incorporate relevant methodologies for doing so.
2) Develop an EPA National Landscape Ecology Workgroup, which is a suggestion born out of the EPA sessions at the United States chapters of the International Association of Landscape Ecology (USIALE) conference in Spring 2004 (personal communication, Luis Fernandez, EPA Region 6) would be a beneficial step in developing more sophisticated and consistent landscape assessment techniques.
3) Take advantage of existing data such as those on forest fragmentation (Riitters et al. 2002) in future Regional critical ecosystem assessments.
4) Functional landscape connectedness or connectivity at landscape scales is a critical property for maintaining ecological integrity. Analyses identifying opportunities to maintain, or restore, habitat connections between large areas of ecological significance should be assessed. At the landscape scale (versus connectivity analysis for particular species), focal areas for connectivity should be riparian corridors (which complements riparian, wetland, and hydrological considerations), ridgelines, opportunities to maintain or restore elevational gradients (to combat global climate change), and other rational opportunities to maximize connectivity and, therefore, minimize fragmentation.

D. Enhancing natural community analyses in Regional critical ecosystem assessments

1) Obtain natural community occurrence data from NatureServe to identify locations of rare natural communities.
2) Conduct representation/irreplaceability analysis of natural communities or natural land covers using one of the several software packages available. A currently ongoing irreplaceability analysis in Region 7 could be the basis for developing procedures for conducting such analyses in all Regions.

3) Increase the number of natural community/land cover types in the National Land Cover Data (NLCD) to enhance representation/irreplaceability analysis. Another option is to use the land cover data of regional (or possibly state) USGS GAP analyses.
4) Consider conducting potential natural vegetation analyses similar to those conducted in Region 5 to augment representation/irreplaceability analysis. Potential natural vegetation can be used to help set representation goals. For example, natural communities that used to be common but are now very rare and are also poorly represented in existing conservation areas should be the highest priority for protection efforts. Potential natural vegetation can also be used to determine the "appropriateness" of land cover types within ecoregions.

E. Enhancing species analyses in Regional critical ecosystem assessments

1) Obtain natural community occurrence data from NatureServe to identify locations of imperiled species.
2) Develop habitat models at least for a few focal species including wide-ranging species or indicators of specific community or landscape types.
3) Where possible, develop spatially-explicit population models for wide-ranging species or other species sensitive to fragmentation at regional scales.
4) Where available, consider using the results of existing assessments such as TNC ecoregional plans or USGS GAP analyses to address habitat or viability assessments for specific species as an alternative.
5) Obtain or collect data, or develop predictive modeling, to identify areas impacted, or with high potential to be impacted, by invasive species.

F. Enhancing natural disturbance regime analyses in Regional critical ecosystem assessments

1) Consider developing analyses that identify areas most likely to maintain, or with the best potential for restoration of, natural disturbance regimes. The Nature Conservancy would likely be a useful partner since consideration of natural disturbances has been incorporated in at least some TNC ecoregional plans. The concept of "minimum dynamic area" should be used as a starting point.

G. Enhancing chemical and physical characteristics, hydrology, geomorphology, and additional stressor analyses in Regional critical ecosystem assessments

1) Work with appropriate EPA entities to develop watershed assessments to identify watersheds with the highest ecological integrity or that are most important for protecting drinking water or other water resources. Two scales of analysis are appropriate. First identify the most significant watersheds using appropriate scale HUC units. Second, areas within watersheds most important for protecting surface water quality should be identified. This work could include the use of pollution sources data, models predicting water quality based on land use data, and possibly source water assessments such as those from the EPA Source Water Assessment Project (SWAP).

2) Where applicable, analyses should be developed to identify where restoration of riparian areas, floodplains, wetlands, or other vegetation would benefit water quality, flood abatement, or other relevant ecosystem services.
3) Determine whether data on acidic and mercury deposition can be incorporated into Regional critical ecosystem assessment projects.
4) Determine whether results of carbon sequestration models can be incorporated into Regional critical ecosystem assessment projects.
5) Consider adding assessment of climate change impacts to identify additional stressors to ecological integrity and to identify areas most important for mitigating impacts to natural communities and species.
6) Monitor the work in development by the Science Advisory Board (SAB) Committee on Valuing the Protection of Ecological Systems and Services (C-VPESS) for recommendations on developing spatial assessments of ecosystem services (http://yosemite.epa.gov/SAB/sabcvpess.nsf/Background?OpenView).

Conclusions

Regional-scale identification of the ecosystems most important for conserving ecosystem services, ecological integrity, and biodiversity (e.g., critical ecosystems) provides an important foundation for proactive and efficient environmental protection. Conservation science elucidates the need for regional-scale analysis and planning to determine how environmental features are integrated, to effectively prioritize conservation efforts, and to provide a rational framework for ecosystem monitoring, protection, and management. Therefore, the identification of critical ecosystems is an essential step in EPA's mission to safeguard the environment for present and future generations.

Geographic Information Systems (GIS) provide the primary tool for identifying critical ecosystems at regional-scales. Over the last two decades, the amount of available data, data quality, and analytical tools have increased rapidly to expand the use of GIS in environmental applications. EPA Regions have done a good job applying GIS to explore identification of critical ecosystems. Current data and tools have allowed various Regions to conduct large scale assessments of critical ecosystems that address most of the categories of analysis contained in the EPA Science Advisory Board's Framework for Assessing and Reporting on Ecological Condition (Young and Sanzone 2002). Therefore, existing EPA projects provide a strong foundation for the next generation of critical ecosystem assessments that should be conducted in all EPA Regions.

This report contains discussion and recommendations for enhancing future iterations of EPA Regional critical ecosystem assessments. As conservation science and GIS continue to develop rapidly, new data and tools are becoming available. Other federal and non-government organization are developing data and tools, or have conducted assessments that are very relevant to EPA efforts. EPA should develop partnerships with various organizations that have expertise in regional-scale ecological analysis including the U.S. Geological Survey and The Nature Conservancy. Specific higher priority recommendations for enhancing future Regional critical ecosystem assessments include:

1) Establish a schedule for development of future iterations of the National Land Cover Data (NLCD)
2) Increase the number of land cover classes in future iterations of NLCD
3) Work with NatureServe to obtain the national database of rare natural community and imperiled species data
4) Consider developing partnerships with The Nature Conservancy, U.S. Geological Survey, and the states to use ecoregional biodiversity data, state and regional GAP analysis, enhanced hydrology data, and state strategic wildlife conservation plan data in critical ecosystem assessments.
5) Conduct representation/irreplaceability analyses for natural communities or land cover types
6) Incorporate habitat modeling and viability assessments for selected focal species
7) Develop methodologies for identifying landscapes with the greatest potential to maintain or restore natural disturbance regimes
8) Develop watershed, riparian, and source water assessments to better identify critical areas for protecting water resources
9) Incorporate data or analyses that identify areas important for carbon sequestration and consider including assessments of climate change to identify additional stressors to ecological integrity and to identify areas important for mitigating impacts on natural communities and species
10) Develop discussions and possibly a workgroup among EPA Regions and other relevant EPA organizations for incorporating review of criteria for identifying critical ecosystems, thresholds for determining ecological significance, and developing feasible sensitivity analyses for regional-scale critical ecosystem assessments. Existing and scheduled Science Advisory Board reviews of the critical ecosystem assessment projects in Region 4, Region 5, and Region 6 could serve as a starting point for these discussions.
11) Develop an EPA repository for data that is not currently readily accessible and a resource guide for locating all other relevant GIS data and tools for conducting regional-scale critical ecosystem assessments that would include methodology guides for using data and spatial tools to address all categories of analysis.

The Regional projects reviewed here have set a high standard for conducting critical ecosystem assessments, and there are many commonalities among existing projects as well as a number of useful unique features that can be used to develop a core set of methodologies applicable to all Regions. This report also represents steps towards cooperation among all Regions to share data and methods for conducting critical ecosystem assessments. The recommendations provide a foundation for future Regional efforts to identify critical ecosystems, and the next challenge is to take existing methodologies combined with new data and tools to develop a common framework of data and methods that facilitates the identification of critical ecosystems in all EPA Regions. The identification of critical ecosystems in all EPA Regions will provide a coherent framework of protection and management priorities, and such a framework will allow EPA to target resources more efficiently and develop better policies and programs to effectively protect environmental quality.